

THE POWER CONTROL USER INTERFACE STANDARD

CONSULTANT REPORT

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to \$62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Energy Systems Integration

What follows is the final report for the Next-generation Power Management User Interface for Office Equipment Project, #500-98-032 conducted by Lawrence Berkeley National Laboratory. The report is entitled The Power Control User Interface Standard – Final Report. This project contributes to the PIER Buildings End-Use Energy Efficiency program.

For more information on the PIER Program, please visit the Commission's Web site at: <http://www.energy.ca.gov/pier/index.html> or contact the Commission's Publications Unit at 916-654-5200.

Executive Summary

The large quantity of energy used to operate equipment and consumer electronics could be significantly reduced if more users could correctly implement energy-efficient power management interface standards when using individual devices. While power management interface controls (labels, terms, symbols, colors, etc.) are present already in hardware and software, often they are used incorrectly or not at all because the user finds them to be confusing, inconsistent, or overly complex. One solution to this problem would be to create a common vocabulary for these controls so that future devices will be easier for people to understand and use, thereby leading to energy cost savings through increased and widespread use of the controls.

Therefore, it was critical that the Power Management Controls Project work with the office equipment and consumer electronics industries to create a new, standard user interface for office equipment power management. The new standard then would have a greater chance of being acceptable to and voluntarily adopted by those industries, standards organizations, and the U.S. EPA's ENERGY STAR program.

This project was conceived to be a combination of research and marketing. The research portion involved reviewing products, standards, literature, and other topics to identify the scope of the interface standard and its specific content. Engaging industry was essential, both to gain valuable feedback, and to give the project more credibility and support. Finally, publicizing the project and its results has been important in order to spread the word.

Objectives

The key objectives of the project were to:

- Create the Interface Standard Development Plan
- Conduct research to guide a new Interface standard
- Develop and test elements of the proposed Interface standards

Outcomes

Based on its objectives, the project had the following primary outcomes:

- Conducted an "Institutional Review," which clearly revealed that no universal standards or conventions currently exist for power management through the use of user interface controls.
- Developed and tested a draft Standard Interface based on broad industry input provided by the Professional Advisory Council (PAC).
- Conducted or instigated four separate tests of portions of the draft Standard Interface.
- Integrated test results and comments from the PAC and others into a final Standard Interface that includes the key elements listed below.

Static Interface

- Use only three power states when possible: *On*, *Off*, and *Sleep*.
- Use the word "Power" for terminology about power.

- Redefine the \cup symbol to mean “power” as for power buttons and power indicators; use the \odot symbol (on/off) only when necessary.
- Use the “sleep” metaphor for entering, being in, and coming out of low-power states; use the moon symbol — \smile — for *sleep*.
- Adopt “green/amber/off” color indications for power state indicators.
- Present PC “hibernate” modes as a form of *off*.

Dynamic Behavior

- Use “power up” to mean turn on or wake up, and “power down” for turn off or go to sleep.
- Use flashing green on the power indicator for powering up and flashing amber for powering down.
- Provide optional audio indications for power state transitions.
- Alternating green/amber can be used to mean error if red is not available.
- Power buttons should toggle between the two most common power states.
- When a device is *asleep*, pressing the power button will (usually) wake it up.
- Holding down a power button for an extended time will trigger an emergency action.
- Introduced and promoted the Project and the new Standard Interface through presentations, conferences, web sites, and personal contacts.
- Examined relevant international standards and identified obstacles to incorporating the proposed standards.
- Created an IEEE (Institute for Electrical and Electronic Engineers) Working Group to transform the project results into an IEEE standard.

Conclusions

A Power Control User Interface Standard has been successfully developed showing that a core foundation for power controls can be established and demonstrating the value of working with all interface elements across diverse device types to form a coherent interface. It is clear that no previous attempts had been made in this area and that industry was not sufficiently motivated by the topic to address it. However, we are cautiously optimistic that the standard has, and will continue to, gain adherents and proponents. A solid foundation has been designed; it now needs to be implemented in further work through integration into an IEEE standard.

We showed how human interface considerations can determine the success of a technology, in this case power management, and that improved interfaces — if reasonable and low-cost — will be adopted by industry. This has implications for other aspects of energy use that are increasingly influenced by user interfaces. These include space conditioning, lighting (as it becomes more electronic and networked), and real time pricing.

The Power Control User Interface Standard will be a tool that makes it easier to save energy once it is incorporated into future products. Some PAC members and others have said that they have begun using parts of the Standard already, though specifics were not available because

products have not been released yet. Use of the Standard and energy savings will grow as it is ratified by standards organizations and incorporated into labeling programs.

Recommendations

Recommended actions for the Commission to take in the future include:

- Support finalizing and implementing the Standard via outreach and IEEE.
- Explore other areas for user interface improvement and standardization related to energy consumption such as lighting, space conditioning, and real-time pricing.
- Consider human interface elements in future mandatory efficiency standards.

Benefits to California

Past Commission work with standards has been mandatory and focused on building construction (Title 24) or equipment sales (e.g. appliances, Title 20) in California. This project demonstrates that for *some* end uses, voluntary standards, and a national or even international focus may be the best way to gain results in California.

Office equipment is largely an international market, meaning that manufacturers market the same models across the globe. Thus, it is necessary to aim for success in changing product designs globally to most effectively influence the devices sold and used in California. Consumer electronics have been traditionally marketed nationally, but manufacturers are increasingly selling the same models internationally, much like office equipment.

Earlier work by LBNL found that the “power management gap” for office equipment in the U.S. in 2000 resulted in costs of about \$1.3 billion per year — costs that could be saved through reduced energy consumption if power management was enabled on all devices capable of performing it. In addition, there were indications that in the absence of efforts to the contrary, the gap was likely to rise in the future (due to an increased number of devices and device types with multiple power modes, greater differences between active and sleep levels, and increased availability of devices offering more hours per year). California’s portion of this gap is likely to be greater than our 12% population share of the country. How fast the standard will be incorporated into new products and how much of the gap is closed by this or other reasons is difficult to assess, but savings of \$100 million dollars per year just in California seem attainable.

Abstract

The goal for the Power Management Controls project was to create a standard for the user interface elements used in power controls with the expectation that incorporating these into future projects would increase the portion of devices that have power management enabled and saving energy. The key objectives of the project were to:

- Create the Interface Standard Development Plan
- Conduct research to guide a new Interface standard
- Develop and test elements of the proposed Interface standards

The major accomplishments of the project were the successful development and testing of a power control user interface protocol, the packaging of this protocol into a draft IEEE (Institute for Electrical and Electronic Engineers) standard, and the creation of an IEEE working group. This set the stage for converting the project recommendations into an IEEE standard, possibly amending international standards, conducting further outreach, and incorporating the standard into the design of future products.

In the process of creating the standard, we assembled a Professional Advisory Committee (PAC) made up of representatives of major hardware and software manufacturers. The committee reviewed project plans and results. Our background research included a review of the relevant literature and national and international standards (and responsible committees). We introduced and marketed the project and standard through presentations, conferences, web sites, and many personal contacts. And finally, we conducted four separate tests of the standard.

Key elements of the Power Control User Interface Standard are to:

- Use only three power states when possible: *On*, *Off*, and *Sleep*.
- Use the word “Power” for terminology about power.
- Redefine the \cup symbol to mean “power” as for power buttons and power indicators; use the \odot symbol (on/off) only when necessary.
- Use the “sleep” metaphor for entering, being in, and coming out of low-power states; use the moon symbol — \smile — for *sleep*.
- Adopt “green/amber/off” color indications for power state indicators.
- Present PC “hibernate” modes as a form of *off*.
- Use “power up” to mean turn on or wake up, and “power down” for turn off or go to sleep.
- Use flashing green on the power indicator for powering up and flashing amber for powering down.
- Provide optional audio indications for power state transitions.
- Alternating green/amber can be used to mean error if red is not available.
- Power buttons should toggle between the two most common power states.
- When a device is *asleep*, pressing the power button will (usually) wake it up.
- Holding down a power button for an extended time will trigger an emergency action.

Other parts of the standard cover the “dynamic behavior” of devices (i.e., behavior of indicators in transition or error states, transition metaphors and audio indications, state changes caused by power button use). The report includes a draft of the IEEE standard, and appendices describing the rationales behind the standard, a literature review, accessibility to the disabled, color choices in indicators, the wider standards context, issues around the crescent moon symbol, and testing of the standard. The project web site (<http://eetd.lbl.gov/Controls>) includes all project documents, related background information, and post-project activities.

1.0 Introduction

The Power Management Controls project addressed user interface elements such as terms, symbols, and indicator lights. The core result of this project was a “User Interface Standard” for future electronic products that should increase the enabling of power management and hence save energy. Although the overall project objective was to achieve energy savings by improving power management, the content of the standard is independent of the amount of the savings so the quantitative energy discussion is kept to Section 2. In this section we present the background context of the project, the specific project objectives, and the organization of the report.

1.1 Background and Overview

The power control user interface is the combination of manual and automatic controls and indications of power status. It includes terms, symbols, colors, operating metaphors, and the behavior of the device in response to input and equipment operation over time.

User controls for power management of office equipment show little consistency in the terms and symbols used and in their overall structure. This is particularly true across device types (e.g. between a PC and a copier), but often holds true even within the same type of device. For example, the *standby* mode on some copiers refers to the state when they are fully on and immediately ready to act, but the *standby* mode on other computers and monitors refers to a low-power mode in which they have reduced capability and take time to recover. “Standby power” also is used to identify a device’s minimum power state, which is often its *off* state. The confusion and ambiguity of so many power management controls often discourage people from using them, or even attempting to do so.

A second deterrent to optimal use of power management is that users often cannot ascertain the power status of office equipment easily, so they don’t know when they should change settings (assuming they do know how to).

Controls that are highly configurable — adaptive to user behavior or informed by daily or weekly calendars — also raise the specter of over-complexity. Delaying the development of standard power management user interfaces will make it even more difficult to gain convergence in the future. We still have the opportunity to develop and standardize user-friendly interfaces.

While the focus of this project is primarily office equipment (and, secondarily, consumer electronics), the principles and standards apply to many other types of devices. Reducing the confusion caused by disparate user interface systems will improve consumer satisfaction. Improved comprehension will lead to additional energy savings as people operate their systems more effectively. In addition, the success of power management controls standardization could stimulate a follow-on effort for residential energy controls (e.g. home lighting and space conditioning systems) and for non-energy controls such as imaging (printing and copying), and water use. Power management in office equipment is a logical first effort in this larger domain.

The original name for this project was the “Next-generation Power Management User Interface for Office Equipment”. This is rather unwieldy for general use, so we began to refer to it as the “Power Management Controls” project. The name of the proposed standard developed during the project is the “Power Control User Interface Standard,” or the “User Interface Standard.”

We use the term “information technology” and the abbreviation “IT” because IT better encompasses the equipment under consideration, and it includes a larger set of devices than office equipment. Office equipment (e.g. PCs) is the most important subset of IT equipment, although, increasingly, less of it is being used for office functions or in offices. For clarity, power “modes” (states) are italicized, e.g. *on*, *sleep*, and *off*.

1.2 Energy Context of Office Equipment and Power Controls

1.2.1 Energy Use of Office Equipment and Savings from Power Management

Office equipment today is responsible for about 2% of total U.S. electricity consumption (Kawamoto et al., 2001). Consumer electronics and other electronic devices only add to this figure. Office equipment also requires the output from about a dozen large (1,000 MW each) power plants. Californians consume less electricity per capita than the United States as a whole, but the office equipment component is probably more intensive than the United States average. Thus, the portion of California’s electricity devoted to office equipment is likely considerably higher than the national average.

The problem of large amounts of energy being used by office equipment was first noted in the late 1980s, and by the mid-1990s a solid and comprehensive program for energy-efficiency was operating (ENERGY STAR). Electricity savings from power management of office equipment has been one of the premier success stories for the energy efficiency community. ENERGY STAR was largely responsible for creating aggressive low-power — or “*sleep*” — modes in nearly all forms of office equipment. The devices can automatically shift into the low-power *sleep* mode after a user-determined length of inactivity, and then quickly recover for use when needed. Engaging *sleep* modes offers large energy savings, as shown in Figure 1 .

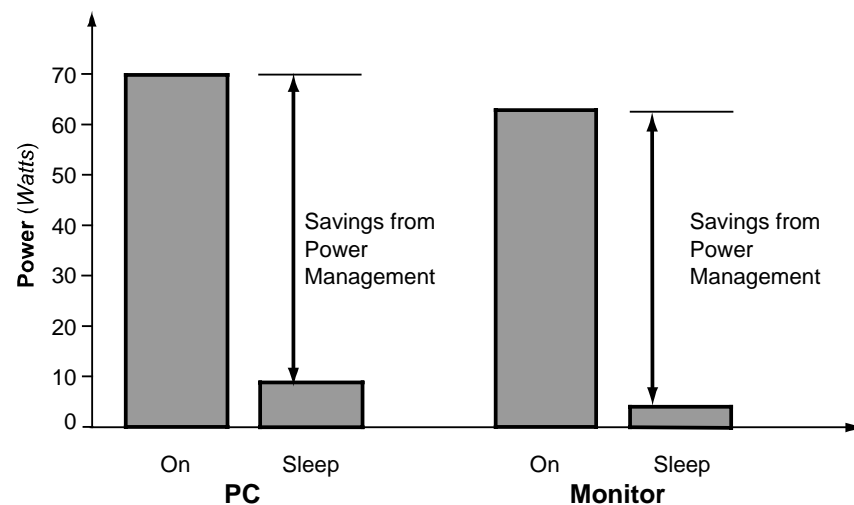


Figure 1. Example power management savings from a monitor and PC¹

¹ The power levels shown here are from (Roberson, 2002) which reports power levels for recent PCs and monitors.

Despite this success, many devices that are capable of power management are not saving energy because the power management features are disabled, incorrectly configured, or thwarted by hardware or software conflicts. The rates of power management enabling vary widely with the kind of equipment and situation. No truly representative national surveys of enabling rates have been undertaken. Limited surveys have been undertaken (see Table 1), and their findings indicate that the majority of PCs do not have power management enabling capabilities. For monitors, printers, and copiers the enabling rates are above 50%, but significant improvement is still possible.

Table 1. Observed rates of power management enabling in office equipment

Device	Enabling Rate
Personal Computers	25%
Monitors	55%
Copiers	70%
Printers	80%

Notes: The figures for Personal Computers, copiers, and printers are from (Nordman, 2000). The monitor figure is from (Webber, 2001).

Thus, if higher power management enabling rates can be achieved, considerable additional electricity can be saved. The goal of this project was to demonstrate a way to capture those savings by increasing the rate at which power management is enabled and operates successfully. The mechanism is a standard for power control user interfaces. Nearly all of the commercial electricity customers in California (and many residential and industrial customers as well) will benefit from these savings.

The most comprehensive and applicable study of office equipment energy use was conducted at LBNL and presents a snapshot as of the end of the year 1999. Table 2 shows the results for the U.S. as a whole, and our estimate for California, which assumes that the state has similar usage patterns and equipment densities per capita as the rest of the country. Those results are the total office equipment electricity use, and the potential *additional* savings if all IT equipment with power management capability was enabled to do so.

Table 2. Office Equipment Energy Consumption and Savings from Power Management

	United States	California
Total Office Equipment Electricity Use (GWh/year)	71,100	8,500
Potential Savings — 100% Power Management (GWh/year)	16,700	2,000
Likely Impact of the User Interface Standard (GWh/year)	5,800	700
Savings of each 1% of Potential (GWh/year)	170	20
Total Office Equipment Electricity Cost (\$mil/year)	5,700	1,300
Potential Savings — 100% Power Management (\$mil/year)	1,300	280
Likely Impact of the User Interface Standard (\$mil/year)	470	100
Savings of each 1% of Potential (\$mil/year)	13	2.8

Notes: National consumption and savings are from Kawamoto, 2001. The figures for California take it as 12% of the national figures. All figures annual for end of 1999. Electricity rates are 8 cents/kWh for the country as a whole and 14 cents/kWh for California. The “likely savings” figures are based on achieving 35% of the potential energy savings from increased use of power management. The existing savings from power management are 22.8 and 2.7 TWh/year for the U.S. and California respectively, with a dollar value at the above electricity rates of \$1,800 and \$380 million/year. These existing savings are with respect to *no* use of power management, and the “potential savings” reflect 100% enabling of power management — both with no change in manual turnoff rates.

It is difficult to assess just how much of the potential national or California savings can be captured by implementation of the User Interface Standard. Because the savings figures vary with the assumption of the percentage of savings gained, a simple way to understand the potential is with the effect of *each* 1% of the potential savings. One can easily multiply this by any percentage.

To provide an indication of the likely impact of the standard, we take 10% to 60% of the potential as the range of plausible estimates, and the midpoint of this range is 35% savings. Table 2 shows the “Likely Impact of the User Interface Standard” based on this 35% figure. To put the 35% figure in perspective, it could be accomplished by increasing copier enabling from 70% to 80% and PC enabling from 25% to 50% (that is, bringing PCs to a place well below what has been achieved already in other devices). Note that the potential does not include any existing use of power management — only possible increases in its use. For all of these savings it is important to recognize that they recur each year and require no extra manufacturing cost if changes are implemented during the normal product design cycle.

1.2.2 Future Trends In Power Management Savings

The figures in Table 2 reflect the stock and usage patterns of equipment as of the end of 1999. Savings from the User Interface Standard will occur in future years, after products meeting the standard are designed and sold, and after users gain enough experience with products and operating instructions based on the User Interface Standard to get the benefit of their consistency and clarity. There are forces driving the potential savings both up and down. Trends tending to increase potential savings from power management are:

- *More Types Of Devices With Multiple Power Modes*
Power management will appear in more and more types of products. Devices not

traditionally “electronic,” such as appliances, lighting, and space conditioning, are increasingly getting electronic capabilities. The trends towards greater portability (so that power management is required for extending battery life), and more communication and networking, both increase the range of devices with power management features.

- *More Of Each Device Type*

The sheer number of devices with power management is on the rise, such as more PCs and displays. Wireless networking eases the deployment of many devices in a home or office that all access the same services (processing, storage, and communications).

- *More Hours Per Year Wanted To Be Available*

Operating times are on the rise — devices are wanted to be available an increasing fraction of the time, as people rely on them more and for more functions. Devices need to be available to communicate with other devices in addition to being used by people. As devices become networked, interdependent, and smarter, the number of factors affecting power management will only increase, so that controls will likely become more complex and unwieldy.

- *More Power Difference Between On And Sleep*

The difference in power levels between *on* and low-power modes is increasing, particularly for computers.

Trends that will reduce potential savings are:

- Transfer of efficient technologies from battery-powered to mains-powered devices
- Lower recovery times, removing that as a barrier to enabling power management

And finally, two trends that could increase *or* decrease potential savings are:

- Changes in the active power levels of devices
- More capability to finely control device behavior

We expect that the overall direction of potential power management savings — the combination of all of these factors — will be up, increasing the importance of the User Interface Standard.

In summary, the potential savings of the Standard are substantial and accrue across California, the nation, and the globe. What savings actually are achieved are difficult to assess either in advance or after the fact; they could be substantially more than the figures shown here, as the pool of potential savings is likely to grow, and the percent achieved could be higher than assumed.

1.2.3 Cost Effectiveness

Implementing the User Interface Standard will not raise the cost of manufacture of IT equipment if introduced during the normal product design cycle.

Since implementation of the User Interface Standard costs so little relative to the savings, the cost-effectiveness of the project is high regardless of the savings ultimately achieved (even without including non-energy benefits and possible energy savings from reduced heat loads in air-conditioned buildings). In most energy efficiency endeavors, there is some increased first-cost to manufacture a better appliance or build a better building. While these can pay off quickly, the program or standard design content necessarily depends and is based on the

anticipated extra cost and savings. For the User Interface Standard, however, there are no extra manufacturing costs if introduced during the normal product design cycle. Because of this, the content of the standard depends only on what is clear to people and adaptable to many product environments. The User Interface Standard content is completely independent of the amount of savings projected or attained.

1.3 Project Objectives

The stated objectives at the outset of the project were to:

- Create the Interface Standard Development Plan
- Conduct research to guide a new standard interface
- Develop and test proposed interface standards:
 1. Development process
 2. Testing
 3. Standards adoption

The project was designed to support the PIER program objective of improving the energy cost/value of California's electricity. This goal was to be accomplished by setting the stage for power controls for future electronic products that are easier to understand and, more importantly, consistent from device to device. The improved user interface should make it easier for people to take advantage of the hardware capabilities built into the products they purchase and use.

1.4 Report Organization

The remainder of this report describes the Project Approach, the Project Outcomes, and the Conclusions and Recommendations resulting from the project. A Glossary and References section provide further detail.

Attachment I is a first draft of the proposed standard: "Draft Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments," which we refer to as the Power Control User Interface Standard.

Appendix I provides background and rationale for the specific decisions underlying the standard content. Appendix II is a review of literature relevant to power control user interfaces. Appendix III discusses how these interfaces can be made more accessible to people with disabilities. Appendix IV addresses issues with color choices, particularly for LED power indicators, to make them more accessible to the color-deficient. Appendix V lists relevant existing standards and standards committees (and describes why they are relevant). Appendix VI provides background about how the crescent moon symbol is used within Islam and how it should be best constructed as an international symbol for *sleep*. Appendix VII reviews the several testing exercises conducted in the course of this project. Appendix VIII delves into the "hibernate" mode used on many computers and how it can and should be treated in power controls.

2.0 Project Approach

The Power Management Controls project was divided into two main phases, each of which served a content and institutional purpose. The first phase accomplished the “Create the Interface Standard Development Plan” objective (a process of refining the project plan, not the yet-to-be-written standard). This process took the first six months of the project and culminated in a daylong, in-person PAC meeting in early November of 2000 at the LBNL offices. The intent was to prepare background material explaining the problem, the context, and pointing the way towards a solution, including deepening the project plan. Assembling the PAC facilitated making contacts at companies, and the background material set the stage for the rest of the project.

The second phase addressed the other two objectives: conducting the research to guide a new standard interface, and developing and testing proposed interface standards. These were conducted in parallel, as the structure and details of the proposed interface became apparent in the course of conducting the research. Also, industry reaction to the initial proposals guided the continuing research in a feedback process. Similarly, the testing was conducted in parallel, occurring in three phases that provided feedback to the standard and to the later testing.

Early on it became apparent that the standard could be divided into two distinct portions: the *hard* or *static* interface elements (terms, symbols, and indicator colors), and the *dynamic behavior* of devices (how the device and interface elements respond to changes and transitions). The latter depends on the former, so the six principles that form the hard interface were put out for industry comment first. Dividing it into these two parts helped make each easier to digest at one time for those providing comment.

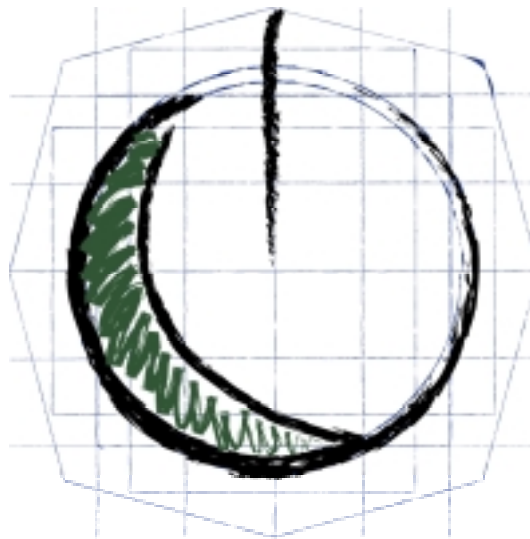


Figure 2. The Final Project Logo

In addition to developing the project content, we also engaged in a variety of outreach activities and methods to publicize the effort and results, get feedback, and collect contacts for marketing the results. These activities included showing posters, submitting papers to conferences,

making individual phone calls, distributing brochures, and contacting media. As part of this, we created two project logos, the second of which is shown in Figure 2².

Because the project is essentially non-quantitative and involves what people see on products, the use of graphics and images was important. We collected several hundred images and dozens of product manuals (or at least those portions that mentioned the power controls). These are some of the raw data of the project — empirical evidence of existing control implementations. The images also evoke ideas and show how the same interface elements can be deployed in widely different ways on products.

A final activity was to determine where to deposit the Standard at the project's conclusion to assure its long-term maintenance and enhance its credibility — in other words, to find a “home” for the standard. Standards organizations are obvious places to consider for this, both national and international. We therefore contacted many standards organizations to determine the best location for the standard.

Much progress in energy efficiency has been accomplished through the use of mandatory standards, as in buildings and appliances. In contrast, experience with the office equipment part of the EPA ENERGY STAR program showed that the electronics industry was willing to work as a whole with outside actors to promote energy efficiency in a voluntary atmosphere. Neither approach is inherently better — it is only an empirical question as to which approach works best for a particular industry or end use at a given time.

Drawing on the lessons of ENERGY STAR, an important method for gaining the interest and support of industry in the process was to emphasize that the results were intended to be strictly voluntary. Avoiding a regulatory framework also suited the nature of the problem; while simple test instruments can objectively measure power levels, user interfaces can be difficult to test for strict compliance with a standard and inevitably get bogged down in minutiae. Finally, as electronic devices and applications evolve, there will be a need to experiment with better interfaces so that worthwhile and intentional innovation should not be stifled.

3.0 Project Outcomes

The major outcomes of the Power Management Controls project are described below, organized according to the project objectives to which they pertain. The details of the content of the standard are found in the appendices; this report focuses on the process.

3.1 Objective 1: Create the Interface Standard Development Plan

The purpose of the first phase of the project was to set the stage for the main research and development of the second phase — to build a solid foundation upon which to work. The foundation was both *content* — plans and anecdotal research — and *institutional* — assembling the PAC.

A first step was to conduct an “Institutional Review” (or “Who is involved in Power Management Controls” as we called it — [Nordman, 2000b]). This was a review of the context

² The final project logo--a combination of the standard grid for designing international graphic symbols, the power (“standby”) symbol, our proposed new moon symbol, and the green color to indicate “on”. All are done in a “sketchy” style to show that we are specifying a framework, not a precise implementation.

of the project and a summary of existing standards and standards committees (international and U.S.), trade associations, labeling programs, manufacturers, and multi-company technology initiatives and protocols. At this early stage it became apparent that graphical symbols were a key topic, and several key standards and committees were identified. Our research confirmed that no existing standard covered the entire power user interface and that our proposal is truly “new”; existing standards take only one aspect (e.g. symbols or indicators) and make no strong or detailed correlation to other standards. There are no U.S. standards that address power controls, with the exception of brief reiterations of international safety standards in U.S. safety standards. In Europe, there is considerable transnational trade within the region so that standards to ensure that this is possible and that national standards are not used as trade barriers. As such, the U.S. is less standards-oriented than is Europe. Since standards activities are more centered in Europe, and the U.S. has only a single vote on standards committees, compared to Europe standards are more often seen in the U.S. as a potential source of problems and less often as a venue for positive change.



Figure 3. The ENERGY STAR Logo

The premier worldwide energy-labeling program is ENERGY STAR (see the program logo in Figure 3). The Power Control User Interface Standard developed in this PIER project is already in the ENERGY STAR monitor specification for 2003 (as a voluntary component), and in the future it will be incorporated into specifications for other products seeking the ENERGY STAR label.

The ACPI (Advanced Configuration and Power Interface) PC interface specification and the VESA (Video Electronics Standards Association) display interface specifications provide critical plumbing for power management. These standards do not directly specify user interface elements, but the terminology of internal protocols is sometimes incorporated into user interfaces.

In summary, the Institutional Review laid out the context within which power controls exist and showed that there was no existing standard or convention occupying the space we intended to fill.

Before the first PAC (Professional Advisory Committee) meeting we investigated the question of intellectual property (IP). If any user interface elements or design principles that we considered as part of the standard were claimed as being owned by a company anywhere in the world, that would be a reason for companies to avoid using them and pose problems for establishing them in standards. Just a claim of IP can be a serious problem, even if it is not valid in the long run, so the research team steered clear of potential IP claims. We concluded that we were unlikely to run into existing claims of intellectual property (e.g. patents or trademarks) in our work due to the nature of the interface elements in question being so common and widespread.

The next aspect of this phase was assembling the PAC and conducting general outreach to industry. For outreach we drew heavily on LBNL's existing contacts with the IT and consumer electronics industries. We sought out contacts at companies that had a large market share, were seen as innovators, or both. In some cases, we found people who were not willing to serve on the PAC, or who did not fit the profile of people we were seeking for the PAC, but who were still interested in following the course of the project. We have built up an email list of such people over the course of the project.

In addition to manufacturers, we sought out representatives from two other organizations: ITIC and the EPA ENERGY STAR program. ITIC is the Information Technology Industry Council, a trade association³; including a representative from ITIC was intended to assure the organization (and by extension member companies) that the project is not a problem for industry, and could actually be a benefit. There were several reasons to include ENERGY STAR as part of the PAC and project generally. For one, the project should help the increase power management enabling rates and thereby increase ENERGY STAR savings. Secondly, the program could be of assistance in outreach and implementation. Finally, the terminology in the standard and in ENERGY STAR specifications can be harmonized, and ultimately the standard can be referenced in ENERGY STAR specifications.

A next step was to update the "Project Plan" (Nordman, 2000c) and then revise it based on the input of the PAC at the first meeting. The plan itself was modified only slightly, with an intended timeline added up front. The more important change was the development of the "Project Scope and Research Topics" (Nordman, 2000d). This document clarified the specific user interface (UI) elements of interest, their location, and the types of devices to address — primarily IT equipment but with some attention to consumer electronics. We also noted areas *not* to address, such as safety, internal mechanisms, and anything subject to intellectual property claims. Then we identified 22 separate topic areas that could be explored. It was clear that we would not necessarily cover all of them, but they mapped out the terrain that we might address. At the meeting, the PAC modified a few of the topics, then ranked them for both their relative priority and the level of effort they deserved. The final list of topics is shown in Table 3.

³ While in principle supportive, trade associations have not expressed much interest in this project. Ironically, disinterest can be seen as a positive sign. Such associations are most likely to get involved when there is something that the industry wants to collectively oppose, so not attracting that type of attention is good. They also get involved when there are developments that may save the industry money or increase market share, and this project does not convincingly do either (though it probably will save support costs from reduced phone calls).

Table 3. Research Topic Names

Priority 1 Topics	Priority 2 Topics
Basic symbols and switches & buttons [L]	Disability [M]
Basic indicators [L]	Culture [S]
Changing power states [L]	Temporary changes [S]
Transition indicators [L]	System status after power failure [S]
Underlying archetype of power management behavior, including basic terms [L]	Terminology [S]
Controlled and controlling devices [L]	Miscellaneous [S]
Remote indicators and controls [L]	
Composite devices and diversity of low-power modes [L]	
Power management ‘schemes’ [L]	
Behavior based on wake event type [M]	
Linked behavior [L]	
Interactions with non-power modes [S]	

Priority 3 Topics
Language [S]
Batteries [S]
Role of the term “ENERGY STAR” [S]
Self-monitoring [S]

Notes: [L], [M], and [S] denote large, medium, and small levels of effort. Priority 1 is most important.

The initial PAC meeting took place at LBNL on November 2, 2000. The companies on the PAC at that time were: Compaq, HP, IBM, Intel, Microsoft, Ricoh, Samsung, Sony, and Sun, in addition to ITIC and EPA⁴.

The PAC reviewed the background material and project plans and then made some amendments to these. Background content prepared for that meeting included a poster describing the problem and the path ahead towards a solution, along with initial examples of existing interfaces. The PAC also carefully reviewed the Institutional Review at the meeting.

Having so many people fly to the November 2000 PAC meeting demonstrated strong industry support, and comments during the meeting confirmed this.

3.2 Objective 2: Conduct Research To Guide A New Standard Interface

One part of this objective was a review of the relevant literature. The project plan anticipated that the amount of existing literature that *directly* addressed the topic was small at best, and in fact, we found no studies that had the power control user interface as a primary topic. There are two types of literature that we did find and report on. A few studies address power controls in passing in some other context; we report on these in discussions where they are specifically relevant. For example, a study on copier symbol recognition included only one power symbol among several dozen copier-related symbols.

The other type of literature that we surveyed was that on user interface design generally. The resulting “Insights from User Interface Literature” (Nordman, 2001, and updated as Appendix

⁴ Nearly all representatives were able to attend. In 2002, Dell joined the PAC.

II) was organized into sections that addressed: Bolstering the Rationale for This Project, Relation to Past Designs, Approach, Design Principles, Metaphor, Modes, Interaction/Transitions, Indicator Lights, Icons, and A Cautionary Tale (about Don Norman's experience with trying to standardize power controls within one company for one type of device — Apple Macintosh computers). The results confirmed assumptions underlying the project, clarified and deepened others, and pointed to issues that we had not previously considered. There is an increasing cadre of IT professionals who see their primary job as “usability” — optimizing products for the user — of which this project is a clear example.

The majority of literature and effort on the topic of usability and good design is intended for people who are designing *all* aspects of a *single* device. However, we are trying to design a *few aspects* of a *wide range* of devices. This makes the basic problem(s) to be solved, and hence data and approaches, quite different — though general principles of good design apply equally as well. Also by contrast, the literature is oriented to more complex interactions (e.g. web site navigation) rather than the more simple and dispersed interaction that people have with power controls.

Explaining this project to others in just a few words has been a challenge from the beginning. We drew upon familiar user interface examples in which standardization has played an important role. An effective example is the touch telephone keypad. We interviewed one of the people on the committee that created the “*” and “#” keys, shortly after the basic arrangement of the 10 digits was established. While the other parts of telephone keypads are not particularly standardized (and neither is the actual meaning of “*” and “#”), the 12 core keys are essentially universal⁵. Traffic signal lights are another good example. There is a vocabulary of meanings that can be adapted to a wide variety of situations (varying color, position, shape, and flashing). While signal lights are not all identical, figuring out what each set does mean is generally easy to do. A final example is automobile gear shifts, in which the basic labeling and structure of the shifting is consistent from vehicle to vehicle even though the number of gears, location of reverse, and physical design details can vary.

The history of the generation of each of these standard interfaces differs; however, once a critical mass was reached, there was great incentive for companies to adhere to that standard. Attaining that critical mass is the goal of the effort of which this research project is a first step.

For field research, we relied on a variety of methods. The single most critical of these was *reviewing owner's manuals* of a wide variety of products for the power control features present and the way they are labeled and explained. An increasing portion of companies makes operation manuals available on the Internet for new products. The PAC specified that the great majority of our effort should be for new products, so the typical lack of on-line information about older models was not a problem. Owner's manuals usually itemize the hardware features present, their behavior, special conditions, and specify the name given to a feature such

⁵ When the “*” and “#” keys were created in the mid-1960s, AT&T was a regulated monopoly and prohibited from being involved in the *content* of telephone calls; it could only provide dialing and connection services. So any usage intended for these keys by AT&T had to be restricted to dialing issues. The people who created the “*” and “#” keys understood that their greatest use would be during calls, not during dialing and making connections, and history has shown them to be correct. To this day, there are no consistent meanings for the two keys, so voicemail and other systems are routinely inconsistent in their usage of them.

as a “power button” (as opposed to an “on/off switch”). Some of the information in the manual could be difficult to discover by inspection, such as that it is necessary to hold down a button for a specific time period for the function to occur and the effect of error conditions. There are limitations, such as that some manuals don’t specify the color of indicator lights or noise or other feedback that occurs during operation. The way that features are explained can be significant, such as PC manuals that say “Your computer has a *sleep* mode and it is called ‘**standby**,’” (emphasis added) which makes clear that the writer thinks that *sleep* is a clearer concept than is *standby*. Owner’s manuals also usually show screenshots of key software control panels.

The other major approach was *direct inspection of devices*, finding devices in homes and offices, at tradeshow, and in stores. The latter two methods were helpful for reducing the number of “old” devices seen and getting a general sense of the relative market share of different interface elements. Direct inspection also allowed photographing selected elements, which is helpful in note taking and for later use in posters, brochures, etc. In most circumstances, however, it is difficult or impossible to identify the full range of interface elements and behavior that an owner’s manual shows, though there are occasional behaviors or other relevant attributes (e.g. that the yellow and green colors used on a particular device’s power indicator are not especially distinct, even to someone with full color vision) that aren’t described in the manual.

An important result of direct inspection (and, to a lesser degree, our inspection of owner’s manuals) is the collection of a *photo library* of elements of interfaces and interface elements. We collected literally hundreds of digital photos that we organized and cropped. These were invaluable in reviewing interface element usage and in preparing presentation slides, posters, brochures, and written discussions.

Some types of data gathering were less successful. We attempted to gain access to those portions of *corporate design guidelines* that address power controls. Several people (PAC members and others) said that such documents exist, but none were able to produce them for our viewing (and apparently in some cases they are not in English). Some power control design decisions are driven by safety guidelines from Underwriter’s Laboratories (UL) and international standards, but these are not company-specific.

Sometimes PAC members and others would refer to internally conducted *usability studies* that helped determine design choices. None of these studies were provided to us, though when pressed it was often revealed that they consisted of showing several design options to a dozen or so co-workers. These types of small, local usability studies can be valuable, but industry seems to try to create the impression that more testing and more comprehensive testing is done than usually seems to be the case.

One of the original intents of the project was to conduct *structured interviews* with product designers about the various design choices made. We ultimately conducted *unstructured interviews*, engaging the interviewees in conversation to elicit the issues and details that they saw as important. We did not use a common structure for discussions with product designers for several reasons:

- We rarely were able to get in contact with the people who made the specific design decisions of interest to us (manufacturers were reluctant to provide names);

- Many design decisions are made in other countries, and it is particularly difficult to pose questions to company personnel in Asia;
- Design decisions about the power user interface seem to be diffuse (no point at which the various elements were considered together);
- Mundane factors such as inertia from previous products or simply using symbols observed on other products in designers' offices were the most common explanations we were given for why specific interface elements were used.

In retrospect, social science theory suggests that unstructured interviews are actually more appropriate in this case. Any structure we used would impose a pattern on people's thinking and an organizational structure that simply does not exist, so our results would be heavily tainted by the particular questions and structure chosen and miss details that didn't fit the pattern.

Our research showed that the interface elements often vary among products from the same company, even within the same type of product (e.g. among PCs, or among printers). For example, power symbols often change from model to model. A major printer manufacturer has placed the power controls in different "menus" on different models. A non-power example is the assignment of functions to "F" or "Fn" keys at the top of computer keyboards, such as those for switching among video output destinations, varies widely even among products from the same manufacturer. The obvious lack of attention to consistency in power controls may have caused manufacturers to be reluctant or unable to talk about the underlying decision-making (or lack of it).

A development in recent years that has been helpful to this project is the rise of "usability" professionals — people whose primary job responsibility is to assess what it is about current or future products that are difficult for people to use and how to change the designs to make them easier. In the case of web pages, the goal is to keep people at a web site and make sure they are not impeded from making a purchase (or whatever the company's goal is). Particularly for hardware suppliers, a concern is to reduce consumer calls to customer support lines. These can easily mount to more than the per-unit margin that a company makes on the sale, so companies are particularly sensitive to them. Products with better user experiences also can improve a company's image and aid future sales. We have found usability experts to be good contacts at organizations as they readily grasp the importance of standardizing the power interface, and are not burdened by too much knowledge of internal implementations that impedes clear thinking about how users actually perceive products.

Anecdotes from manufacturers and ordinary people were a notably helpful type of data to obtain and generally occurred during free-form conversation about power controls. For example, a PC manufacturer representative noted that feedback had been received about consumer confusion over computers with multiple sleep states that had different wake events depending on the sleep state (e.g., in light sleep keyboard or mouse activity would wake it but in deep sleep only the power button would). This would cause people who successfully used the lighter sleep to then assume the machine was broken when confronted with the deeper sleep state that didn't wake from the action that worked earlier. This helped to cement the importance of the principle that within a power state, capabilities and behavior should be consistent. Similarly, we often

introduced people to the topic by pointing to or describing the ☰ symbol at which point a response of “oh, the power symbol” was most common.

We conducted *detailed research* on several topic areas that seemed important. The specifics are described in the Appendices, but examples of these are: The “hibernate” mode, the crescent moon and Islam, selected internal power control mechanisms (principally ACPI), industry specifications (e.g. PC Design Guides), color deficiency, and accessibility in general. Smaller inquiries were made into portable electronic device (PEDs) on airplanes and popular (non-power) usage of symbols.

Delving into *standards* was a major research activity. Most standards are offered for sale rather than being available free on the web, and the University of California library system has very few international standards in its holdings. It is difficult to know which standards might have relevant discussion in them, and there is a labyrinthine network of committees, subcommittees, working groups, national standards organizations, industry standards organizations, and draft and final standards. Also, it is key to know which are commonly observed and which are routinely ignored. Much of this can only be navigated by personal contact, usually by phone or email. Appendix V is a summary of relevant standards and committees.

Much of this project’s research consisted of bringing together information from widely disparate sources into a common framework to reveal or clarify some issue. In several cases we produced new data. One example is the discussion of the “hibernate” state as implemented in a variety of computer systems, including Windows® PCs. It seems clear that the industry has not thought through the issues involved in the detailed and comprehensive way that we did.

Some pursuits came up largely empty. With a few exceptions, accessibility was an example of this. Many people and policies assert the importance of designing products to be accessible to the widest range of users possible. We contacted many people whose primary job function is accessibility and, when pressed for suggestions on how this could be accomplished for power controls, we got a quite limited response. What we did come up with is parts of the dynamic behavior portion of the standard.

3.3 Objective 3: Develop And Test Proposed Interface Standards

Key principles in the standards development process were to identify interface elements that were *common*, and those that were *clear* (and clarity often requires simplicity). This was tempered by the content of existing standards to form our initial proposals. These were then released for comment by the PAC and other industry contacts and revised. The key parts of the standard were subject to several rounds of testing and ultimately formalized in the IEEE standard format.

3.3.1 Developing The Interface Standard

The standard was released for comment in two phases: the first covered the *hard* or *static* parts of the interface, and the second, the *dynamic behavior* of devices. The static part included five initial principles and the groundwork for a sixth (on hibernate). The dynamic behavior portion started with nine principles, one of which was dropped based on PAC input. The critical aspect of the standard as developed is that it all works together as a whole — in stark contrast to existing standards, which treat each interface element (e.g. symbols or indicators) in isolation.

The insights gained from our review of the user interface literature generally were an important factor in shaping the standard development. Another factor was the consideration of a wide variety of devices and applications, a key difference from conventional product design. One example is how to code power states on indicators: with colors or flashing (for *sleep*). Flashing can only be used with displays or lights but cannot serve as a coding in a static way, such as the background color on a shutdown dialog box on a PC or on a mechanical switch. Also, while it might be acceptable for a single device (e.g. a PC) to flash in *sleep*, if all devices did this a future household might have dozens of devices in it, each blinking in its own way and causing great distraction. Another example is the distinction between the ☰ and ① symbols for whether the device consumes zero or non-zero power in *off*. While this can be determined reliably on many devices, it can vary for those that can utilize batteries (which may or may not be present at any given time), and it can be problematic for use in operating systems (in which the software may be unable to know if *off* is zero power or not and therefore be unable to show the proper symbol). A third example is extensibility: the use of the sleep metaphor allows for gradations (e.g. *light sleep* or *deep sleep*) for those products that may have more than one low-power mode, and for convenient phraseology, e.g. “wake up.” This is in contrast to other terms used such as “standby” or “energy-save” that lack both of these attributes. Internationalization is a fourth case, though one more commonly dealt with by existing manufacturers, particularly of IT equipment.

We were also cognizant of areas in which it was not feasible to extend the standard. One example was the specific capabilities that one can expect in the *sleep* and *off* modes. There was significant diversity among products in these modes, and neither mandating capabilities nor disallowing them is a reasonable option. Some devices can be turned on over a network connection and others can't. Some can wake on keyboard input, and others require pressing the power button to wake up. We also were careful to avoid tying the user power states to particular power levels, even for *off*⁶. There is too much variety in devices, their requirements, and the trajectories of future technologies to burden long-lasting user interface conventions with specific quantities. Also, there are already good methods for doing this, such as purchasing mandates (e.g. for standby power), mandatory standards, and voluntary labeling (e.g. ENERGY STAR).

While we tried to stay away from internal mechanisms for controlling power status, in the case of ACPI it was necessary to address some of its detail, since it impacted the discussion of hibernate. It is best if internal systems are not encumbered by the user interface and vice-versa, though consistency in terminology and principles can help avoid conflicts.

It is well known that symbols, colors, and other aspects of user interfaces can be significant in specific cultures. We were attentive to this in the entire process, but it became a major concern only in the case of the crescent moon and Islam. We studied the issue in depth and ultimately concluded that it did not present a problem if a few guidelines were observed in order not to make crescent moons look too Islamic.

⁶ It may seem desirable for the user interface to communicate the difference between zero-power and non-zero-power off-states, but doing so consistently makes the interface that much more complicated and generally would not affect how people operate a device. It also would not indicate how much different from zero any non-zero *off* power state is, so people would not have a rational basis by which to decide if it was significant or not.

The topics that raised the most disagreement among PAC members were indicator colors and how to treat the “hibernate” state. For indicators, there was concern about using color as the only coding mechanism for power state and so instead use flashing for sleep states. We had conducted research showing that color ambiguity can be mitigated and flashing calls attention to itself so the PAC consensus supported the use of colored, non-flashing lights. For hibernate, there remain some individuals within the industry who have difficulty adopting the specification that hibernate is a form of *off*, but the great majority of people do accept this.

3.3.2 Testing The Interface Standard

There were four separate testing exercises conducted for this project — two at UC Berkeley, one at Cornell University, and one at LBNL itself. All focused primarily on the static part of the standard, though questions about power button behavior and flashing indicators helped inform some of the dynamic behavior specifications. The goal was to determine if the proposed standard was as compelling to ordinary people as the rationale behind suggested it ought to be. The *content* of the test results is reviewed in Appendix VII; here, we consider only the *process*.

All of the tests included both explorations — looking for associations and inclinations — and validation — checking to see that the draft standard was consistent with user expectations, or at least not in conflict with them. Table 4 summarizes key information about the tests. In each of the tests, subjects were asked about the meaning of symbols and indicators, and the first three asked about what actions the user would take to cause a specific action to occur.

Table 4. Testing Summary

	UCB1	UCB2	Cornell	LBNL
Respondents	37	12	105	36
Questions	27	43	33	11
Power Symbols	X	X	X	X
Indicators	X	—	X	X
Sleep Associations	X	—	X	—
Use of Sleep Modes	X	—	X	—
Changing States	X	X	X	—
Assessing State	X	—	—	—

The UCB testing provided some practice in what questions to ask and in user reaction that provided useful results and insight as to how subsequent testing should be conducted. The Cornell tests were similar, though they were conducted based on the UCB study plan rather than on direct work with LBNL. The LBNL testing followed the procedure outlined in the project plan, beginning with a plan to be presented to the PAC, a revised plan based on PAC

input, the actual test, and a report summarizing the process and results. The earlier studies were beneficial in helping to improve and focus the LBNL test. Readers are encouraged to view the UCB reports directly⁷.

3.3.3 Adopting the Interface Standard

There are two basic aspects to standards development for this project: the *content* to be embodied as a standard and the *process* and *ultimate destination* for the content.

The content was developed in two parts, but they have been combined into one final document in Attachment I. Standards are traditionally crisp presentations of content with little background or rationale for the choices made in developing them. Part of the reason for omitting the rationale is to facilitate compromises and papering-over of differences among countries, but it seems an unwise way to do business when standards are voluntary or need to be revised or extended. We believe that recording the rationale is vital, at least for this standard, and we present that in Appendix I.

For process and destination, it has to be borne in mind that the standards universe and the real world of products and manufacturers evolve in parallel, only intersecting periodically. Standards proceed slowly, particularly in cases like this that do not make or break products (unlike for example communications protocols such as IEEE 802.11). We do not want any manufacturer to wait until standards processes have finished before implementing the user interface standard, and in fact the use of the standard in products is likely to accelerate the standards process. On the other hand, establishment as an official standard does provide credibility and a mechanism for distributing and updating the content, and the fact of working towards a standard should accomplish some of this. So, it is essential to work along both tracks in parallel.

A logical ultimate home for the user interface standard is the IEC (International Electrotechnical Commission) as this is where the most relevant existing standards reside. However, there is no committee within the IEC that clearly has a mandate to pursue our scope. Thus, immediate progress through the IEC is not plausible. We have been attempting to engage the relevant committees for symbols, but this has been stymied because the U.S. is not a member of the most critical committee (IEC SC 3C). We have yet to identify a committee with U.S. membership that has the ability, mandate, and interest to forward our proposal. Late in the process we concluded that it might be best to separate the two proposals (creating a moon symbol — ☾ — for “sleep” (see Figure 4) and changing the definition of the “standby” symbol — ⏻ — to mean “power”). The sleep symbol is self-contained, and does not directly undermine the historic symbols and their definitions, and so should not be controversial. The change to the ⏻ symbol is likely to bring to the surface lingering disagreements about how it should be defined and used, and it could be interpreted as a criticism of the existing symbols. Thus, it could be controversial and, at a minimum, take longer to gain consensus for.

The near-term opportunity is through IEEE (the Institute for Electrical and Electronic Engineers). IEEE provides a mechanism that is tractable in access (we already have a working

⁷ <http://www.sims.berkeley.edu/courses/is271/f01/projects/PowerControls/>

group created for this standard), geography (no international meetings required), and process (we only need to seek out a domestic balloting community to succeed rather than convince disinterested members of other countries' international standards committees). While the user interface standard is intended to be global, we can expect to have greater initial success with U.S.-based companies for whom IEEE is a more respected standards organization and the IEC is seen as more marginal. Non-U.S. companies typically pay more attention to IEC standards. Furthermore, just recently (November, 2002), the IEEE and IEC came to an agreement about putting a dual logo on key IEEE standards, so that transition of content from IEEE to IEC should be easier in future.

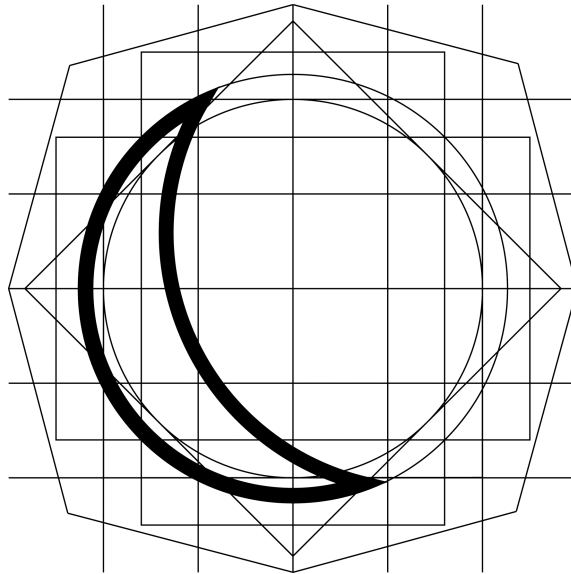


Figure 4. The proposed “Sleep” symbol

Part of developing a new standard is to be comprehensive in identifying relevant existing standards, to refer to, use definitions from, build on, and (as necessary) propose changes. In this process we have found existing standards and ones currently in development that address user interface elements specifically, interface design generally, or topics such as energy test procedures whose terminology could be harmonized with our standard.

Another aspect of standardization is multi-company industry plans and protocols (or actions of a single company, such as Microsoft), is that it can affect the products of many other companies through the operating system. We have attempted to influence these to be compatible with and support the user interface standard. The standard is already included as a voluntary component of the ENERGY STAR monitor specification for 2003, and is to be incorporated into other ENERGY STAR product specifications as they are revised. This is included as “strongly recommended” — not required — consistent with the project premise that a voluntary standard will attract more industry cooperation than a mandatory one. The plan is for EPA to include this in all future electronics specifications as they come up for revision. The Swedish labeling organization (TCO) intends to harmonize many of their specifications with ENERGY STAR and so should incorporate the standard into their specifications. Several companies have indicated that they are using the indicator standard for future products but are reluctant to be explicit until the products are released.

In the course of the project we came across a standard in development for “service indicators” for IT equipment (VITA, 2002). At first glance it appeared that the scope and usage of this standard would conflict with our standard. However, we determined that because of the intended application (data centers and telecommunications facilities) and specific indications and symbols there was no actual conflict. We were able to assist the developers of that standard and ensure that it was not amended to conflict with ours.

The ACPI specification is already consistent with the standard except in how it presents the Hibernate state. Future VESA (Video Electronics Standards Association) standards may be able to incorporate elements of the standard; we are monitoring this. Intel sponsors a web site called




Formfactors.org, which provides standard chassis specifications for the reference of manufacturers. Future specifications could reference the user interface standard. Microsoft included a paper by Bruce Nordman (Nordman, 2002b) in its 2002 WinHEC (Windows Hardware Engineering Conference) and could include the user interface standard (or parts of it) in future white papers by Microsoft employees.

3.4 The User Interface Standard Content

Key elements of the User Interface Standard — the static interface — are to:

Use only three power states when possible: On, Off, and Sleep.

Use the word "Power" for terminology about power.

- Redefine the  symbol to mean “power” as for power buttons and power indicators; use the  symbol (on/off) only when necessary.
- Use the “sleep” metaphor for entering, being in, and coming out of low-power states; use the moon symbol —  — for *sleep*.
- Adopt “green/amber⁸/off” color indications for power state indicators.
- Present computer “hibernate” modes as a form of *off*.

For the “dynamic behavior” of devices, the standard specifies:

- Use “power up” to mean turn on or wake up, and “power down” for turn off or go to sleep.
- Use flashing green on the power indicator for powering up and flashing amber for powering down.
- Provide optional audio indications for power state transitions.
- Alternating green/amber can be used to mean error if red is not available.
- Power buttons should toggle between the two most common power states.
- When a device is *asleep*, pressing the power button will (usually) wake it up.
- Holding down a power button for an extended time will trigger an emergency action.

Usually, when a device is *asleep* the input causing a wake event should be discarded.

Attachment I presents the content of the standard in more detail and Appendix I reviews details of the background and rationale for the choices made in developing the Standard.

3.5 Technology Transfer

While much of this project was traditional research and development, a key part of it was introducing and “marketing” the concept and results to the target industries. This involved creating the marketing materials and bringing them to individuals, groups, and organizations. It was important to do this early so that organizations knew they were consulted and had the opportunity to comment — even if they ultimately didn’t end up having substantive feedback.

⁸ For purposes of power controls, the terms “amber,” “yellow” and “orange” are taken as synonymous.

The industry plans and protocols discussed throughout the report are examples of institutions we have been working on influencing. Other avenues are described in the following paragraphs.

We presented the project to the PC Ease of Use Roundtable⁹ three times in the course of the project (April, 2000; August 2001; and June 2002). This is an opportunity to reach many PC manufacturers at once, and the very goal of that group is the means we seek to achieve our energy savings objective. In fact, prior to our project they were beginning to work on power management, but deferred their own efforts to this project.

We took the poster to the IBM Make IT Easy conference twice (June, 2001; June, 2002), and to the 2000 ACEEE Summer Study on Energy Efficiency in Buildings (August, 2000).

Presentations were made at LBNL (December, 2001), the VESA annual conference (April, 2002), an ENERGY STAR meeting on revising the monitor specifications (April, 2002), to an innovative product design company (Lunar of San Francisco in April, 2002), at the Commission's workshop on standby power (August, 2002), to a U.S. standards committee (IEC TC 108 TAG in October, 2002), and at the 2002 ACEEE Summer Study on Energy Efficiency in Buildings (August, 2002). Brochures were sent to several conferences. Finally, the most important mechanism for outreach has been the telephone, supplemented by email; hundreds of calls have been made to spread the word.

Articles on the project have appeared in MIT's TechnologyReview.com (June, 2002) and in the Ease of Use Roundtable Newsletter (October, 2002).

Outreach materials we produced in the course of the project include two posters (and sub posters to accompany them), two brochures, and a series of Powerpoint® presentations, all of which are on the project web site. The web site itself is an important part of outreach, and it has received the compliments of many in its visual design. The web site will be similarly important in the steps ahead.

While the main effort of this project was making the case for the merit of and need for the standard, and details required for the development process, manufacturers have been asking for more simple and concise summaries of how to implement the standard in future products.

Finally, the standards development process is a core part of dissemination.

⁹ The Ease of Use Roundtable meets about six times a year to work on issues that impede user purchasing of PCs and causes support and other costs to manufacturers that may be alleviated by making PCs easier to use.
<http://www.eouroundtable.com/>.

4.0 Conclusions and Recommendations

The major conclusions and recommendations of the Power Management Controls project are presented below.

4.1 Major Conclusions

This project made significant progress towards a future with consistent and clear power user interfaces for electronic devices, one with much greater savings from power management. Our development of the Power Control User Interface Standard shows that a core foundation for power controls can be established and that it is necessary to work with all interface elements together across diverse device types to form a coherent interface.

The division of the standard into static and dynamic portions was helpful in organizing the research and presentation.

It is clear that no previous attempts had been made in this area, and therefore it was important for that vacuum to be filled. It is also clear that the relevant industries were not sufficiently motivated by the topic to address it on their own. However, we are optimistic that the standard has and will continue to gain adherents and proponents. A solid foundation has been designed; it now needs to be implemented in further work and, later, extended and deepened.

This project also demonstrates the importance of user interfaces that affect energy use and that improving them is a viable energy-saving strategy. This has implications of other aspects of energy use that are or will increasingly be influenced by user interfaces. These include space conditioning, lighting (as it becomes more electronic and networked), appliances, and real time pricing.

Past Commission work with standards has been mandatory and focused on buildings constructed (Title 24) or equipment to be sold (e.g. appliances) in California. This project demonstrates that for *some* end uses, voluntary standards and a national and even international focus are appropriate. California is significantly affected by international trends (such as standards) and in turn the state can have an impact on international products and energy use.

4.2 Commercialization Potential

In the context of this project, “commercialization” means incorporation of the standard into products sold to consumers. Many products already comply with the standard in part, and some do entirely (particularly some simple ones). There is no technical barrier to commercializing the standard; the barriers are inertia and lack of attention to the topic. The potential is nearly 100% of the market in the long run. In between, product model lines need to be turned over (manufacturers will not change this aspect of the user interface of an existing model), and some internal technical implementation issues need to be solved (specifically, transition indicators for PCs). The Power Management Controls project has been a success in setting the stage for commercialization.

4.3 Benefits To California

The energy quantification of the potential savings from more use of power management was conducted prior to the project initiation, but for a variety of reasons future potential savings will be even larger. Based on the results to date, the technology developed under the Power

Management Controls project appears very likely to generate substantial economic and environmental benefits to California ratepayers in the years to come.

If all U.S. office equipment in 2000 that had power management capability had been optimally utilized, an estimated \$1.3 billion per year of direct electricity could have been saved (Kawamoto et al, 2000). Improved controls will not save all of this because there are other reasons why power management is not always utilized. However, with modest assumptions about savings the project may attain, California's share of savings from the standard could easily be \$100 million/year. For a variety of reasons cited in the background section, the power management opportunity — and so savings from the User Interface Standard — can be expected to grow.

4.4 Recommendations

Recommendations for future action are organized below.

- Recommended LBNL Actions:
 - Continue to host the Power Management Controls web site.
 - Pursue other research projects that bring user interface issues to energy consumption and savings.
- Recommended Commission Actions
 - Support finalizing and implementing the Standard via outreach and IEEE.
 - Explore other areas for user interface improvement and standardization related to energy consumption such as lighting, space conditioning, and real-time pricing.
 - Consider human interface elements in future mandatory efficiency standards.
- Recommended Actions by Others
 - ENERGY STAR should continue to incorporate the standard into future specifications.
 - Manufacturers of IT equipment, consumer electronics, and other electronic devices should design their products in accordance with the standard.

5.0 Glossary

ACPI	Advanced Configuration and Power Interface — A specification of the interface among a PC operating system, BIOS (Basic Input – Output System), hardware, and other system devices. http://www.acpi.info
CEC	California Energy Commission — A state of California agency.
Enabling rate	The portion of devices that have their power management features turned on.
ENERGY STAR	A product-labeling program run by the U.S. Environmental Protection Agency and U.S. Department of Energy.
IEC	International Electrotechnical Commission — An international standards organization oriented to electrical and electronic products and applications. http://www.iec.ch
IEEE	Institute for Electrical and Electronic Engineers — A membership organization of professionals in the electrical and electronic fields, one of whose functions is the development of standards. http://ieee.org
IP	Intellectual Property — such as patents, trademarks, etc.
ISO	International Organization for Standardization — An international standards organization with a broad mandate. http://www.iso.ch
IT	Information Technology — Office equipment such as computers, printers, etc.
ITIC	Information Technology Industry Council — A trade association of leading companies in the IT field. http://www.itic.org
LBNL	Lawrence Berkeley National Laboratory — A U.S. Department of Energy National Laboratory in Berkeley, CA. http://www.lbl.gov
PAC	Professional Advisory Committee — A group of people, mostly from IT and CE companies, who review project results and periodically meet to discuss and approve them.
PED	Portable Electronic Device — A consumer device on an airplane that could theoretically produce radio frequency emissions that might interfere with airplane navigation.

PIER	Public Interest Energy Research — A research program of the CEC.
Power Control User Interface	The combination of manual and automatic controls and indications of power status. It includes terms, symbols, colors, operating metaphors, and the behavior of the device in response to input and over time.
TCO	A Swedish trade union organization that runs a labeling program similar to ENERGY STAR, but with added ergonomic and environmental requirements.
UL	Underwriters Laboratories — “an independent, not-for-profit product safety testing and certification organization” (from the ul.com web site)
User Interface	The mechanisms by which an electronic device communicates with a user to provide status information and control capability. It can include both hardware and software.
WinHEC	Windows Hardware Engineering Conference — An annual meeting sponsored by Microsoft to explain company initiatives related to the Windows platform and get feedback from manufacturers.

6.0 References

References below are listed in two categories:

1. Materials published in the general literature
2. Materials published on the project web site (<http://eetd.LBL.gov/Controls>).

Materials Published In The General Literature

Compaq, Intel, Microsoft, Phoenix Tech., and Toshiba. 2000. Advanced Configuration and Power Interface Specification: Revision 2.0. [http://www.acpi.info]. 2000.

IEC 1998. Graphical symbols for use on equipment. IEC 60417. First Edition, Geneva, Switzerland: International Electrotechnical Commission. Part 1: Overview and application; Part 2: Symbol originals. 1998.

ISO/IEC 2000. Collective Standard: Graphical symbols for office equipment. ISO/IEC 13251. First Edition, Geneva, Switzerland: International Organization for Standardization and International Electrotechnical Commission. 2000.

ISO 1989. Graphical symbols for use on equipment: Index and synopsis. ISO 7000. Second Edition, Geneva, Switzerland: International Organization for Standardization. 1989.

Kawamoto, Kaoru, Jonathan Koomey, Bruce Nordman, Richard E. Brown, Maryann Piette, and Alan Meier. 2000. Electricity Used by Office Equipment and Network Equipment in the U.S. Published in the Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings. Washington, D.C.: American Council for an Energy-Efficient Economy. 2000.

Kawamoto, Kaoru, Jonathan G. Koomey, Michael Ting, Bruce Nordman, Richard E. Brown, Mary Ann Piette, and Alan Meier. 2001. Electricity used by office equipment and network equipment in the U.S.: Detailed report and appendices. LBNL-45917. Berkeley, CA: Lawrence Berkeley National Laboratory. 2001

Kawamoto, Kaoru and Jonathan G. Koomey, Bruce Nordman, Richard E. Brown, Mary Ann Piette, Michael Ting, and Alan K. Meier. 2002. Electricity used by office equipment and network equipment in the US. *Energy—the International Journal*. vol. 27, no. 3, pp. 255-269. March, 2002.

Nordman, Bruce, Alan Meier, and Mary Ann Piette. 2000. "PC and Monitor Night Status: Power Management Enabling and Manual Turn-off." In Proceedings of the ACEEE 2000 Summer Study on Energy Efficiency in Buildings, 7:89-99. Washington, D.C.: American Council for an Energy-Efficient Economy, 2000a.

Nordman, Bruce, Alan Meier and Don Aumann, "Fixing the Power Management Controls Problem", 2002 ACEEE Summer Study on Energy Efficiency in Buildings, Washington, D.C.: American Council for an Energy-Efficient Economy, 2002a

Roberson, Judy A., Gregory K. Homan, Akshay Mahajan, Bruce Nordman, Carrie A. Webber, Richard E. Brown, Marla McWhinney, and Jonathan G. Koomey, "Energy Use and Power

Levels in New Monitors and Personal Computers”, LBNL-48581, Berkeley, CA: Lawrence Berkeley National Laboratory, 2002.

Rosen, Karen, Alan Meier, and Stefan Zanelin. 2000. “National Energy Use of Consumer Electronics in 1999” *In Proceedings of the ACEEE 2000 Summer Study on Energy Efficiency in Buildings*, 7:89-99. Washington, D.C.: American Council for an Energy-Efficient Economy.

VITA, 2002, 40-2002: Service Indicators, VITA Standards Organization, Fountain Hills, AZ.

Webber, Carrie A., Judy A. Roberson, Richard E. Brown, Christopher T. Payne, Bruce Nordman, and Jonathan G. Koomey. 2001. *Field Surveys of Office Equipment Operating Patterns*. LBNL-46930. Berkeley, Calif.: Lawrence Berkeley National Laboratory. 2001.

Materials Published on the Project Web Site

(Intermediate documents produced during the course of this project; all by Bruce Nordman unless otherwise noted, and all available at: [<http://eetd.LBL.gov/Controls>]).

The Standard

“Dynamic Behavior”, August, 2002.

“Toward a Standard User Interface for Power Controls”, April, 2002 included in the conference papers for the Microsoft Windows Hardware Engineering Conference (WinHEC) and available at the WinHEC Conference web site. [<http://www.microsoft.com/winhec/>], 2002b.

“Tentative Recommendations”, July, 2001.

“Designing the new Moon Symbol” and a precise drawing, June, 2002

Other Results

“The Power Control User Interface Standard: Fall 2002 Testing Results and Conclusions”, October, 2002; also the slide sets used in the testing process (September, 2002).

“Power Switch Labeling - for Medical and Other Devices”, November, 2002.

“Insights from User Interface Literature”, July, 2001. 2001a.

“Who is involved in Power Management Controls?”, December, 2000, the "Institutional Review", 2000b.

“Sleep, the Crescent Moon, and Islam”, May, 2002.

Testing

“User Perceptions of Power Controls, Icons and Power States” by Jonathan Puleio and Jenna Shanis, Cornell University, 2002.

“Testing the User Interface Standard: UCB Survey Results”, May, 2002.

“On, Off, or Asleep?: User Perceptions of Power Controls on Common Office Equipment” by Azeen Chamarbagwala, Phoebe Kuan-Ting Liu, Craig Rixford, Mary Trombley, and Bin Xin, SIMS, University of California, Berkeley, October, 2002.

“Power Controls -- Form and Function: Mapping the User's Mental Model”, Craig Rixford and Azeen Chamarbagwala, SIMS, University of California, Berkeley, December, 2002.

“Instructions for Powering your PC”, June, 2001.

“Hibernate”, September, 2002.

“Industry (PAC) Comments on UI Standards Recommendations”, May, 2002.

“Project Questions”, January, 2002.

“Field Testing the User Interface Standard”, May, 2002.

Project Plans

“Project Scope and Research Topics”, December, 2001, 2000d.

“Project Timeline”, December, 2001.

“Updated Project Plan”, December, 2001, 2000c.

Agendas and meeting summaries for each Professional Advisory Committee (PAC) Meetings.

IEEE P1621

December 15, 2002

Draft Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments

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of the
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Introduction

(This introduction is not part of IEEE P1621, Draft Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments.)

The electronics industry has been proactive in including product features that reduce power levels when possible to save energy, and extend battery life. Much of this has been accomplished through industry work with the U.S. EPA ENERGY STAR program, and globally, billions of dollars of electricity are saved each year through the use of power management¹. Despite this success, many devices that are capable of power management are not saving energy because the power management features are disabled, incorrectly configured, or thwarted by a hardware or software conflicts². For PCs, the great majority are not power-managing. For monitors, printers, and copiers, the rates are above 50%, but significant improvement is still possible. Thus, there is the potential for considerable additional savings through higher enabling rates in power management. In addition, there are a variety of reasons to expect that the opportunity for energy savings from power management will only increase in coming years, such as more devices and device types that can power manage, greater number of hours these devices are wanted to be available, and greater difference between on and sleep states.

The goal of this standard³ is to capture energy savings by increasing the rate at which power management features are enabled and operate successfully. This standard should lead to other benefits such as improved ease of use and reduced burden of customer support on manufacturers.

At present, power management controls in office equipment and other electronic devices show little consistency in the terms, symbols, and indicators used and in their overall structure. This is particularly true across device types (e.g. between a PC and a copier), but often holds even within the same type of device. For example, the standby mode on some copiers refers to the state when they are fully on and immediately ready to act, but the standby mode on some computers and monitors refers to a low-power mode in which they have reduced capability and take time to recover. “Standby power” also is used for a device’s minimum power state, which is often when it is off. The combination of controls and indications of power status is the user interface.

The confusion and ambiguity of so many power controls precludes many people from being able to understand power controls and power status. The problematic interfaces further deter these people and others from attempting to change power management settings or successfully doing so.

This standard is intended to accomplish a broad similarity of experience of power controls of any electronic device that is used in a normal work or home environment. It is intended to do this through voluntary means. It is not intended to stifle innovation in user interfaces, nor preclude deviations from the standard where clearly warranted.

The first draft of this standard is based on research conducted at Lawrence Berkeley National Laboratory, and funded by the Public Interest Energy Research (PIER) program of the California Energy Commission.

¹ Kawamoto, Kaoru and Jonathan G. Koomey, Bruce Nordman, Richard E. Brown, Mary Ann Piette, Michael Ting, and Alan K. Meier. 2002. Electricity used by office equipment and network equipment in the US. *Energy—the International Journal*. vol. 27, no. 3, pp. 255-269. March, 2002.

² Nordman, Bruce, Alan Meier, and Mary Ann Piette. 2000. “PC and Monitor Night Status: Power Management Enabling and Manual Turn-off.” In *Proceedings of the ACEEE 2000 Summer Study on Energy Efficiency in Buildings*, 7:89-99. Washington, D.C.: American Council for an Energy-Efficient Economy. Also, Webber, Carrie A., Judy A. Roberson, Richard E. Brown, Christopher T. Payne, Bruce Nordman, and Jonathan G. Koomey. 2001. *Field Surveys of Office Equipment Operating Patterns*. LBNL-46930. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

³ This Draft Standard was initially published as Attachment 1 to California Energy Commission report #P500-03-012F, available at www.energy.ca.gov/pier/buildings/reports.html

December 15, 2002

IEEE P1621/D<number>

The report of that research (The Power Control User Interface Standard⁴) is available at the project web site: <http://eetd.LBL.gov/Controls> and on the Energy Commission website (#P500-03-012F at www.energy.ca.gov/pier/buildings/reports.html).

At the time this standard was completed, the working group had the following membership:

Bruce Nordman, *Chair*

The following members of the balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention. (To be provided by IEEE editor at time of publication.)

⁴ Nordman, Bruce, "The Power Control User Interface Standard — Final Report". Lawrence Berkeley National Laboratory. P500-98-032. Contract No. 500-98-032. LBNL-52526. December, 2002.

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Draft Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments

1. Overview

1.1 Scope

This standard covers the user interface for the power status control of electronic devices that ordinary people commonly interact with in their work and home lives, including, but not limited to, office equipment and consumer electronics. Key elements are terms, symbols, and indicators.

This standard does not: specify maximum power levels; address safety issues; or cover internal mechanisms or interfaces for industrial devices.

1.2 Purpose

To accomplish a similarity of experience of power controls across all electronic devices so that users will find them easier to use and be more likely to utilize power management features that save energy.

2. References

This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply. See Annex A for informative references. Uniform Resource Locators (URLs) provided in this standard are current as of the date submitted for publication.

CIE Technical Report CIE 107-1994, Review of the official recommendations of the CIE for the colours of signal lights, International Commission on Illumination.

IEC 447:1993, Man-machine interface (MMI) — Actuating principles.

IEC 60073:2002, Basic and safety principles for man-machine interface, marking and identification—Coding principles for indication devices and actuators.

IEC 60417-1:1998, Graphical symbols for use on equipment—Part 1: Overview and application.

IEC 60417-2:1998, Graphical symbols for use on equipment—Part 2: Symbol originals.

IEC 59/267/CD:62301:2002, Measurement of standby power. Draft.

IEC 80416-1:2001, Basic principals for graphical symbols for use on equipment—Part 1: Creation of symbol originals.

IEC 80416-3:2002. Basic principals for graphical symbols for use on equipment—Part 3: Guidelines for the application of graphical symbols.

ISO 7000:1989, Graphical symbols for use on equipment: Index and synopsis.

ISO 9186:2001, Graphical symbols—Test methods for judged comprehensibility and for comprehension.

ISO 9241-10:2001, Ergonomic requirements for office work with visual display terminals (VDTs)—Part 10: Dialogue principles.

ISO 9241-1:1996, Ergonomic requirements for office work with visual display terminals (VDTs)—Part 1: General introduction.

ISO/IEC 13251:2000, Collective Standard—Graphical symbols for office equipment.

VITA 40-2002, Service Indicators.

3. Definitions, terminology, and acronyms

In this standard, to increase clarity, power states are *italicized*.

3.1 General Definitions

3.1.1 device: An electronic machine, usually a commercial product, that is commonly used and interacted with by ordinary people in their work or home life. This includes devices traditionally electronic, such as office equipment and consumer electronics, as well as appliances, telecommunications devices, space conditioning equipment, and any other device that has non-trivial power controls. In this context, devices are usually separately powered from the mains, separately controlled by the user for their power status, and have a separate power indicator.

3.1.2 manual power control: An action taken by a user, or external device (including network activity), to change the power state of the device.

3.1.3 power control: The combination of manual power control and automatic power management.

3.1.4 power control panel: A set of software controls for viewing and/or changing parameters relevant to the power controls such as delay timers, switch behavior, summaries of usage patterns, and device behavior after unexpected power loss.

3.1.5 power indicator: A color, word, or other display that communicates the power state of a device to a user. Common examples are simple lights (e.g. a light emitting diode), text display (e.g. with a liquid crystal display), or an element of a larger visual display. Power indicators may also have audio or tactile indications.

3.1.6 power management (automatic): The active modulation of the energy consumption of a device for purposes other than the intended function of a product. Examples of other purposes are mains electricity conservation, battery life extension, overheating avoidance, and noise reduction from less fan noise.

3.1.7 power state: A condition or mode of a device that broadly characterizes its capabilities, power consumption, power indicator coding, and responsiveness to input. Basic power states are *on*, *sleep*, and *off*. Devices may have multiple instances of one or more of the basic states (e.g. *light sleep*, *deep sleep*), and need not have any *sleep* states. All devices have at least one *on* state, and at least one *off* state (*unplugged*). The term “power mode” may be substituted and has identical meaning.

3.1.8 power switch: A user mechanism for causing a power state transition. May also be called a “power button”.

3.1.9 tactile nib: A small raised surface, usually on a key, that does not interfere with normal usage but allows identification of the key through tactile means only. May be also found on buttons or switches. Common examples are “F”, “J”, and “S” keys.

3.1.10 wake event: A manual or automatic action that causes a system to initiate a transition from a *sleep* power state to an *on* power state.

3.2 Power State Definitions

3.2.1 hard-off: An *off* power state in which the device uses no power from the mains or a normal operating battery.

3.2.2 on: A power state in which the device has greater (or similar) power consumption, capability, and responsiveness than it does in the *sleep* or *off* state.

3.2.3 off: A power state in which the device has less (or similar) power consumption, capability, and responsiveness than it does in the *sleep* or *on* state.

3.2.4 sleep: A power state in which the device has greater (or similar) power consumption, capability, and responsiveness than it does in the *off* state, and has less (or similar) power consumption, capability, and responsiveness than it does in the *on* state.

3.2.5 soft-off: An *off* power state in which the device may use some power from the mains or a normal operating battery. When it is unknown whether the *off* power is zero, the *off* state shall be considered to be *soft-off*.

3.2.6 unplugged: A form of the *off* power state in which all normal operating power supplies have been disconnected. For devices that can operate from battery power, this requires that the battery be removed or otherwise disconnected from the ability to supply the system. A device that is unplugged cannot be turned on until at least one source of the power supplies is connected. Incidental battery power such as that which supplies clock circuits but is not capable of powering the device in an *on* state does not qualify as normal operating power. A battery which provides only short-term operating power (e.g. for less than 1 minute) also does not qualify.

4. The Standard

4.0 General Principles

This standard shall not be used to impede innovation in power controls, nor shall it be used to prohibit deviations from the standard in cases where the difference is clearly merited. The standard shall be interpreted in ways that maximize consistency across devices and simplicity and clarity for users.

4.1 Power States

Power states for this standard are *user* power states, and are not required to correspond directly to internal power states. Devices shall be limited to the three basic power states — *on*, *sleep*, and *off*. Any additional power states shall be variants of one of the basic states rather than a fourth state.

This standard does not address absolute power levels, nor does it make specifications about peak power consumption so that no restriction is placed on short-term fluctuations in power levels.

Power levels for purposes of this standard are only relevant as they affect long-term energy consumption. Thus, power should be measured over an extended time period; IEC 62301 provides procedures for measuring average power over such periods.

The only power consumption requirements of this standard for power states are that:

$$\text{Power}_{\text{ON}} \geq \text{Power}_{\text{SLEEP}} \quad \text{and} \quad \text{Power}_{\text{SLEEP}} \geq \text{Power}_{\text{OFF}}.$$

Common forms of *sleep* are *light sleep* and *deep sleep*. As with basic power states, $\text{Power}_{\text{LIGHT SLEEP}} \geq \text{Power}_{\text{DEEP SLEEP}}$.

Common forms of *off* are *soft-off* and *hard-off*. *Soft-off* implies that some power may be consumed by the device even though the power state is *off*. *Hard-off* requires that no power is consumed, either from mains power or a normal operating battery.

4.1.1 User Experience of Power States

The *off* power state does not require information about the device functional state to be lost. For example, a television may remember the channel and volume settings when *off*, and a computer may remember its functional state in *off* through the use of a “hibernate” feature, saving the system state to non-volatile memory (e.g. a hard disk).

When feasible, devices shall have consistent behavior, responsiveness to input, and capability to act in all substates within a basic state. For example, wake events shall be consistent across all sleep states when feasible.

Users shall not be required to understand the differences among substates to properly use a product, but devices are not prohibited from communicating which substate the device is in.

When feasible, user interfaces shall not differ between *soft-off* and *hard-off* except when the *hard-off* symbols need to be used. Users should generally experience only *off*.

4.1.2 Relation between Power States and Operating System State

The state of a device operating system and the power state of the device shall be differentiated, but may have common controls. For example, a command to power on a device may also start the operating system, and a command to power down may also shut down the operating system. However, a device can be in a special mode and be *on* but without the primary operating system operative, and a device can be *off* but have the operating system state saved for immediate use after power on (this is commonly called “hibernate”).

A command to “restart” a device operating system is generally not a power state transition, since the device usually begins and ends in the *on* state. However, it is appropriate to present a restart operation as a pair of power state transitions (power down immediately followed by power up).

4.2 Power Symbols

Power symbols shall be those used in IEC 60417 as well as the sleep symbol. The are listed in Table 1. IEC 60417 defines \cup as for use with a power switch that does not do a total mains disconnect, and hence the device consumes “standby” power. \cup is generally used and understood to mean “power”, as on power buttons, indicators, and elsewhere. \cup therefore means “power” with a non-zero power level in the *off* state. Electronic devices shall use \cup to be a synonym for “power” on power controls. Even if used on a power button that does go to a *hard-off* state, that should not introduce any safety issue.

Table 1. Power Symbols

Symbol	Name	Usages in addition to use within power control panels
I	On	On a switch, best used in conjunction with the Off symbol, as on a rocker switch.
○	Off	On a switch, best used in conjunction with the On symbol, as on a rocker switch.
⓪	On/Off	For use on a power switch that always switches to <i>hard-off</i> in the <i>off</i> state. For use with a power indicator if the off indication is always <i>hard-off</i> and the distinction from <i>soft-off</i> is important.
Ⓢ	Power	For use on a power switch or button if the <i>off</i> state is <i>soft-off</i> , is variable, is not known, or the distinction from <i>hard-off</i> is not important. Also for use with a power indicator, or as the icon for the power control panel.
☾	Sleep	For use on a sleep button, or with a sleep indicator.

In accordance with IEC 80416-3, symbols can be filled, rotated, have their lines thickened, or used on digital displays, so long as the meaning remains clear.

4.3 Power Metaphors, Affordances, and Terminology

Metaphors and affordances can be used in the construction of terminology, documentation, and product design. For power controls, they should be used as described below, but used precisely and sparingly.

Power states shall be understood to have physical relationships to each other. Specifically, *on* is taken to be above *sleep*, and *sleep* above *off*. Consequently, “power up” refers to a transition from *off* to *on*, *off* to *sleep*, or *sleep* to *on*. “Power down” refers to a transition from *on* to *off*, *on* to *sleep*, or *sleep* to *off*. “Power on” refers to transition to an *on* state. “Power off” refers to a transition to an *off* state.

For low-power modes, the “sleep” metaphor shall be used, for the name of the power state, for transitions (“going to sleep”, “waking up”, and a “wake event”), and for the sleep symbol—☾.

User terminology used for controls for power states shall be organized around the term “power”. Common examples include a “power switch”, “power button”, “power indicator”, “power control panel”, and “power management”. User terminology is often used on the outside of devices; in documentation, and on displays.

For power indicators, the colors and color names “yellow”, “amber”, and “orange” shall be considered to be equivalent, though orange is the least preferred. This standard uses the name “yellow” to be consistent with IEC 60073. The specific colors to use are specified in Section 4.4. Care should be taken when translating the color names to other languages that the term used for yellow is clearly not that used for any form of “red”.

Common terms used to refer to *on* states are *on*, *full-on*, *ready* and *active*, but no difference in meaning is implied by this standard to these different terms.

Standard translations of key terms shall be used in documentation, and on products (when present). Key terms include: power, *sleep*, *on*, and *off*.

4.4 Power Indicators

4.4.1 General Principles

Power indicators shall communicate stable device power states or transitions between power states. Power indicators may also communicate non-power-state information provided that ambiguity is not introduced.

4.4.2 Static Power States

For power indicators, color coding for power states shall be green for *on*, yellow for *sleep*, and off for *off*. Black or gray may be substituted for off (as on a graphic display or with a mechanical indicator). These color assignments are consistent with IEC 60073.

For *sleep* indicators, color coding for power states shall be off for *on*, yellow for *sleep*, and off for *off*.

Power indicator colors shall be used in accordance with CIE 1994, which specifies color limits for traffic signal lights. For fully saturated colors, green shall be between 498 *nm* and 508 *nm*; yellow between 585 *nm* and 593 *nm*; and red between 615 *nm* and 705 *nm*.







For text or graphic displays, *on* can be specified by the lack of power-state information (and presence of other information), the term “on” (or a clear synonym), or the on symbol—; *sleep* states can be communicated by the term “sleep” or the sleep symbol—; the *off* state can be communicated by the display being off, use of the term “off”, or the off symbol—. Table 2 presents a summary of power state indications.

Table 2. Summary of power state indications

State/ Term	Indicators		Symbol	Text / Displays
	Power	Sleep		
On	green	off		The lack of power-state information (and presence of other information). “On” may be substituted by a clear synonym,
Sleep	yellow	yellow		The term “sleep”.
Off	off	off		The display being <i>off</i> , or use of the term “off”.

Power indicators may be on remote devices. For example, a computer may display the power state of other devices it can connect to. This allows indications of an *off* state other than an indicator light or entire display being off.

Some mechanical switches can reliably show the power state so long as the device is powered.

For devices for which a constantly illuminated power indicator would use excessive energy or be particularly intrusive, a brief flash of the power indicator in the appropriate color is allowed (e.g. one tenth of a second on followed by 1.9 seconds off).

Non-power information can be combined with power indications in the following ways. An error indication can be shown with a red color in the place of a power indication; when this is done, no power state information is communicated. When red is unavailable, alternating green and yellow at the normal flashing rate can be used to indicate an error, but shall not be used to indicate that a safety hazard is present. Alternating red and green or red and yellow shall be used to simultaneously indicate an error condition and power status. Other non-power-state information, such as communication occurring, can be indicated by the slow flashing rate. Per IEC 60073, normal flashing rates are 1.4 Hz to 2.8 Hz, and slow flashing rates are between 0.4 Hz to 0.8 Hz.

4.4.3 Power State Transitions

From the user perspective, some devices change from one power state to another instantly. For devices with user-perceptible transition times *between* states (e.g. more than one second), the power indicator shall communicate the fact of the transition state and its direction. Even for instant transitions, a “blink” of the indicator is recommended as it helps the user to see that the transition has occurred.

Color power indicators shall flash or otherwise modulate during transitions, green for a “power up” transition, and yellow for a “power down” transition. Text or graphic indications shall flash or provide some other indication that there is a transition state. Flashing shall be consistent with IEC 60073 normal flashing rates (1.4 Hz to 2.8 Hz).

Devices with audio capability shall have optional audio indications of power state transitions. The audio indications shall be of one of the types shown in Table 3.


Table 3. Audio indications of power state transitions


Type	Details
Click	A power-up transition shall be indicated by a single click or beep. A power down transition shall be indicated by a double click or beep.
Tone	Powering up shall be indicated by a rising tone or two tones with the second having a higher pitch than the first. Powering down shall be indicated by the reverse (a falling tone or two tones with the second having a lower pitch than the first). <i>Sleep</i> shall be accommodated in these indications by using a tone with a pitch intermediate between the two tones used for <i>on</i> and <i>off</i> .
Other	Other sound indications (e.g. musical notes or speech) shall clearly indicate the direction or endpoint of the transition.

Devices with extended transitions and the capability to display a progress indicator shall display one. A progress indicator shall show (via graphics or text) the estimated elapsed portion of the total transition time or the time remaining in the transition.

4.5 Power Switch Labeling and Behavior


When feasible, pressing a power button shall toggle the device between the two most commonly used power states. When a device is asleep, and can wake itself up, pressing a power button shall wake up the device.

Power switches shall be one of two types: *hard-off* and *soft-off*. When safety is involved, the user interface shall be unambiguous as to whether an *off* state is *soft-off* or *hard-off*. When safety is not involved, preference shall be given to the  symbol.

The present set of international standard symbols for power control lacks a workable designation for *soft-off*—equipment that are functionally *off* but continue to draw some power (the  symbol is reserved for zero power). Thus, designs should be avoided that would require such a symbol.

It is recommended that rocker switches be used for power controls only when *off* is a zero power state. It is also recommended that push-button switches be used for power controls when *off* is non-zero power. These usages avoid the need for a symbol that clearly means the *off* power state, but means *soft-off*.

When a device has two power controls, or otherwise has a *hard-off* and *soft-off* mode (with the *hard-off* obtainable other than by unplugging from the mains or normal battery), both will have the power indicator

off. Only inspection or manipulation of the power switches will clarify which mode it is in. When two power controls are present, the secondary control should be labeled with .

For devices which need an emergency override, it shall be accomplished by holding down a power button for at least four seconds. An emergency override will usually force the device into an *off* state and is necessary when ordinary means to do this are not possible.

In product design, consideration shall be given to the specifications of IEC 60073 for actuators for *on* and *off*. However, this standard makes no requirements for actuator colors. Among the specifications of IEC 60073 are that for a control that goes to *off*, red may be used and green shall not be used; for controls to go to *on*, green may be used and red shall not be used; and for controls that switch among power states, neutral color such as white, grey, and black are preferred, yellow and green are not to be used, and red is to be used only in special circumstances.

4.6 Wake Events

Devices with *sleep* states shall have one more wake events. When feasible, wake events shall be consistent across all *sleep* states. When feasible, pressing a power button shall cause a wake event.

For general purpose controls such as keyboards, and where the meaning of a key press depends on mode information not apparent in the *sleep* state, the wake event itself shall be discarded from the normal input stream.

4.7 Tactile Interfaces

When a tactile marking is used on a power control, it shall be a single nib or set of three nibs in a horizontal line on the power button or on the “on” side of a power switch.

Tactile indications of states and transitions shall be broadly consistent with those of the other modalities of this standard.